

New and updated ~~ISIS~~ Cartographic applications for small bodies

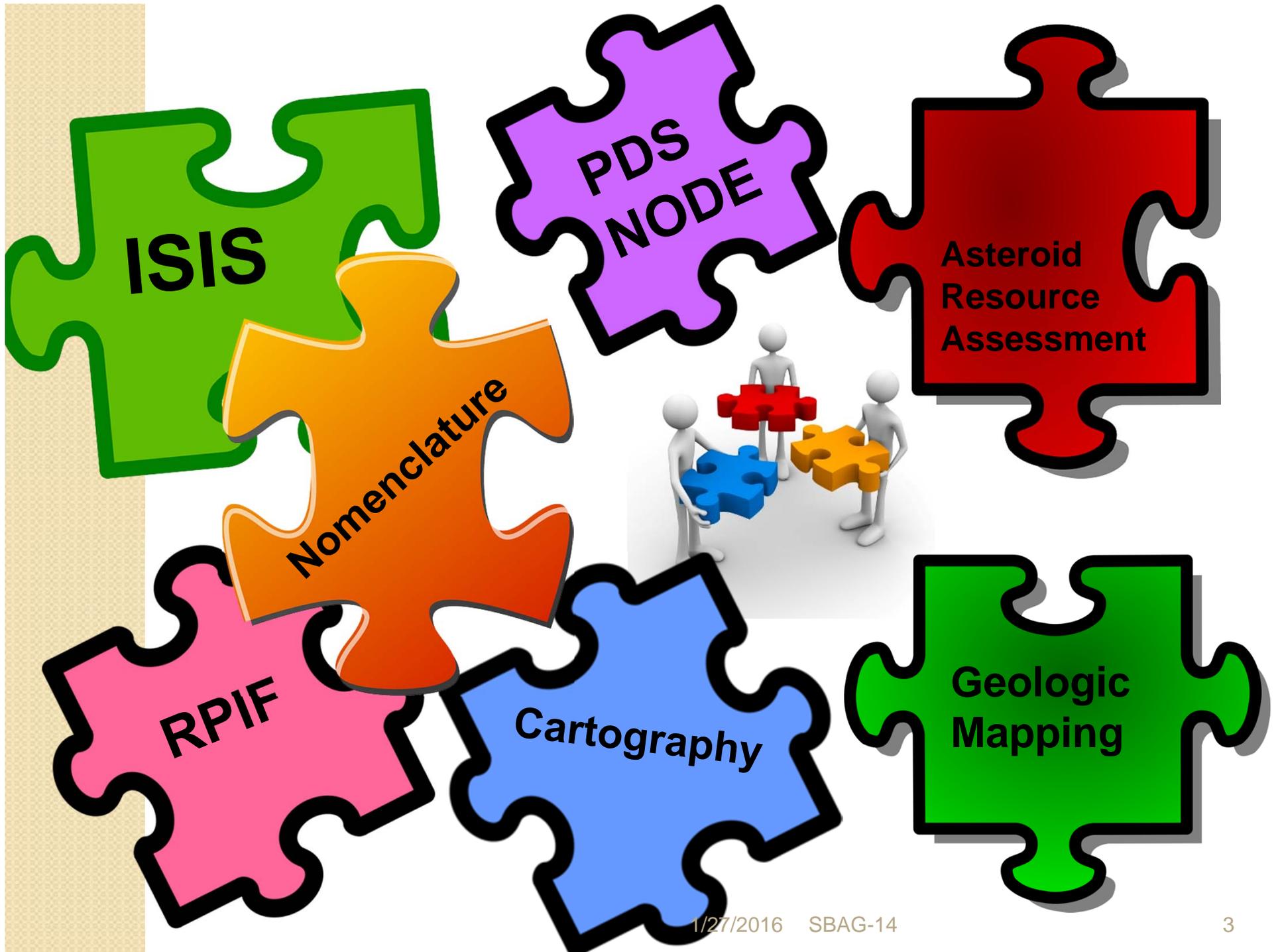


Titus, Becker, Becker, Edmundson, Gaddis, Hagerty, Hayward, Kestay, Portree, Sides, et al.

Cartography is more than just making a paper map.

- Raw Data/Images
- Metadata (e.g. SPICE)
- Benchmarks/Control Points
- Project/Orthorectify
- Construct Mosaics
- Construct Maps
- Distribute Maps



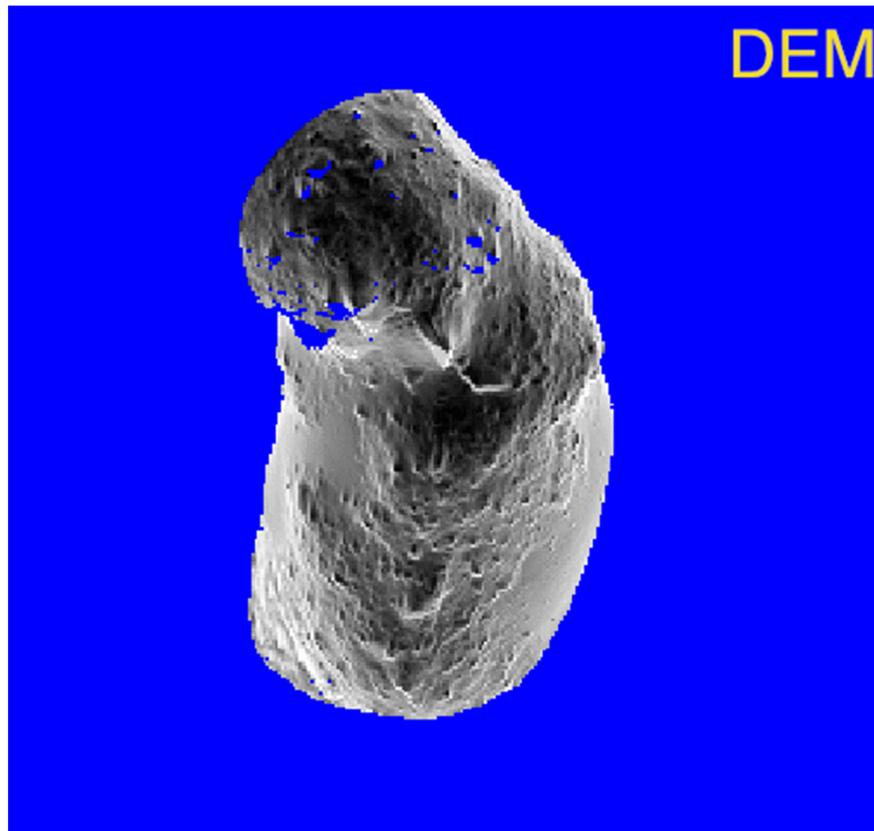




Integrated Software for Imagers and Spectrometers

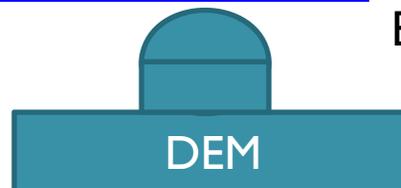
- Improvements in shape models
 - Standard Radius Files
 - Digital Shape Kernel (DSK)
 - Need to improve oblique projects with “real” topography
- New Tools for Network Control (Beta)
- Image and Data Viewers
- Mission Support

Digital Shape Kernel (DSK)



- DEM (Radius) is the standard ISIS default for shape models.
- DEM is really on 2.5D
- DSK is a TIN and therefore truly 3D

Example of a Rock on the surface





Hayabusa 25143 Itokawa

- AMICA instrument support provided in ISIS
 - Ingestion application (*amica2isis*)
 - Camera model with support for all 8 filters
 - Radiometric calibration (*amicacal*) in progress
- Control and cartographic maps
 - AMICA images have up to 12 seconds of start time uncertainty
 - Requires control to produce quality color cartographic products
 - Photometric correction in progress
- Development of *sumspice* ISIS3 application to correct timing and apply Gaskell control
 - Successfully applied to 711 of 773 images

sumspice Functionality

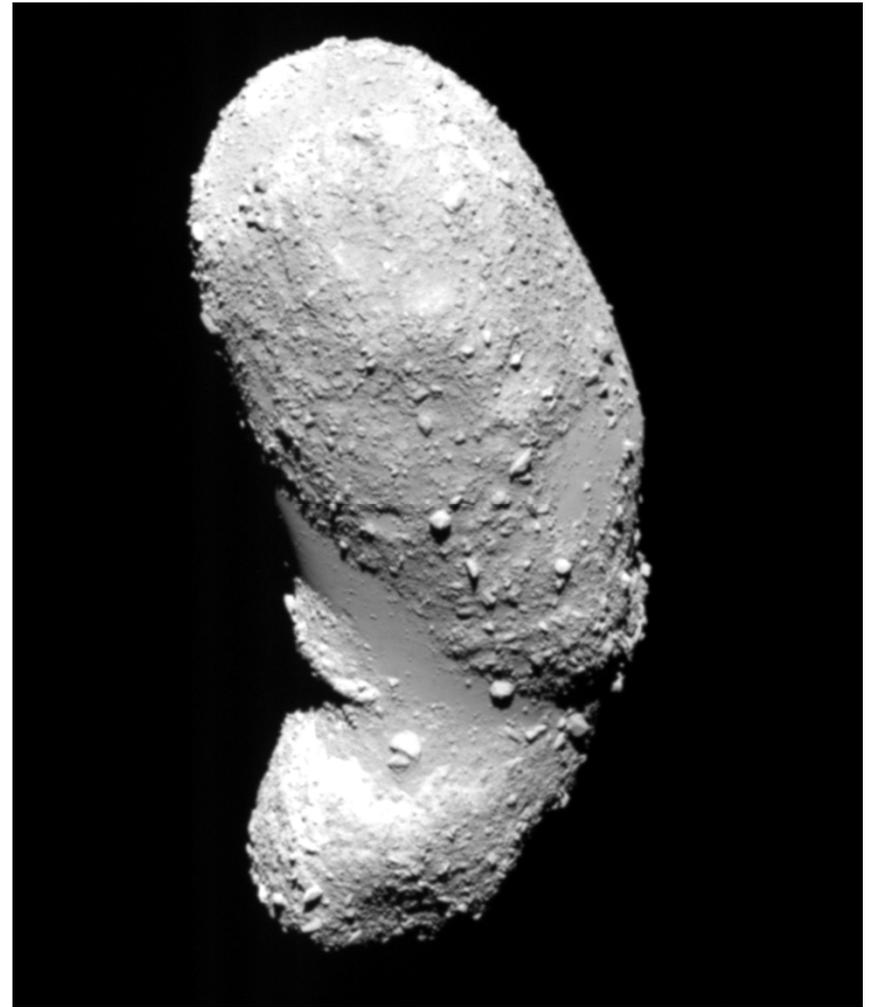
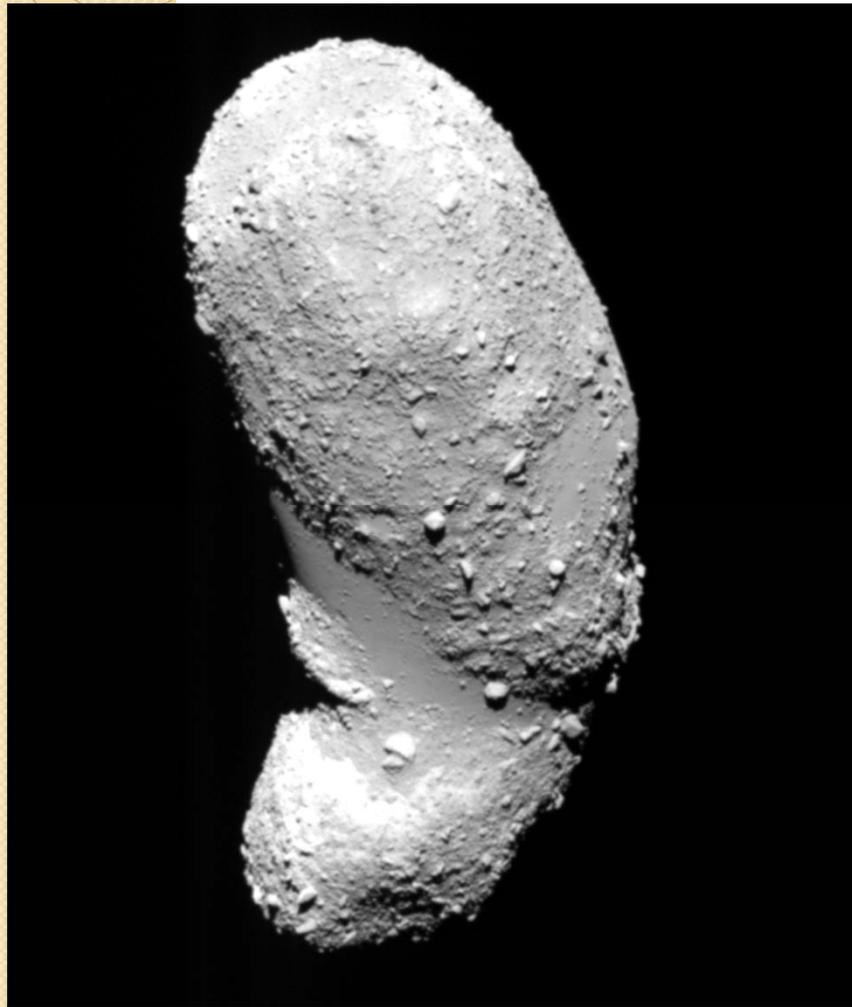
- Gaskell produced 25143 Itokawa DSK shape model using stereophotoclinometry (SPC) techniques (2008)
- Uses Gaskell SUMFILES as adjustment/correction source
 - SUMFILES are created for each image included in Gaskell DEM generation
 - Contains, among other things, image start times, corrections to spacecraft attitude (CK) and position (SPK)
- Timing uncertainty greatly reduced by analysis of relative pointing between LIDAR and AMICA (ONC-W2)
 - AMICA image statistically adjusted to simulated images of Itokawa using small time increments
 - Very small misalignment likely due to difference in camera (distortion?) model
- Gaskell attitude (CK) and position (SPK) coordinates replace SPICE stored in ISIS cubes
- Can then create new CKs and SPKs with *ckwriter* and *spkwriter*, respectively
- Comparisons made using ISIS *phocube* application and Gaskell Itokawa DDRs
 - Gaskell DSK DEM to create geometric/photometric backplanes

sumspice Alignment with Gaskell

SPC DSK DEM

Apriori

DN vs Phase *sumspice* w/Gaskell



Feature-based Control Process

- Control networks using ISIS3 feature-based image matching rather than area-based matching (*findfeatures*)
 - OpenCV API that has (at least) 11 feature detector, 6 extractor and 2 matcher interchangeable algorithms
 - Algorithms fully parameterized at command line
 - Uses OpenCV threaded API for simultaneous image matching
- Add robust outlier detection of image matcher (*findfeatures*) with four main steps
 - Bi-directional ratio test of two closest matches of each tie point
 - Symmetry test of bi-directional matches
 - Epipolar (stereo) constraints from fundamental matrix using random sampling consensus (RANSAC)
 - Projective relationship using homography (rotation) matrix
 - This is significant improvement because outlier detection is now performed *both* in the matching phase and bundle adjustment!

Control Software Summary

- New software developed in ISIS for image-to-image control
 - *isisminer* – main control and data manipulation application
 - *findfeatures* - feature-based image matching using OpenCV API
 - *cnetcombinept* – enhanced version of *cnetmerge* that focuses on combining control points rather than control networks
 - *cnet2dem* – creates digital elevation model directly from bundle adjusted control networks
- Existing ISIS software applications used
 - *footprintinit*
 - *camstats*
 - *caminfo*
 - *cnetcheck*
 - *jigsaw*
 - *ckwriter*



Control of MESSENGER MDIS Orbital Image Dataset

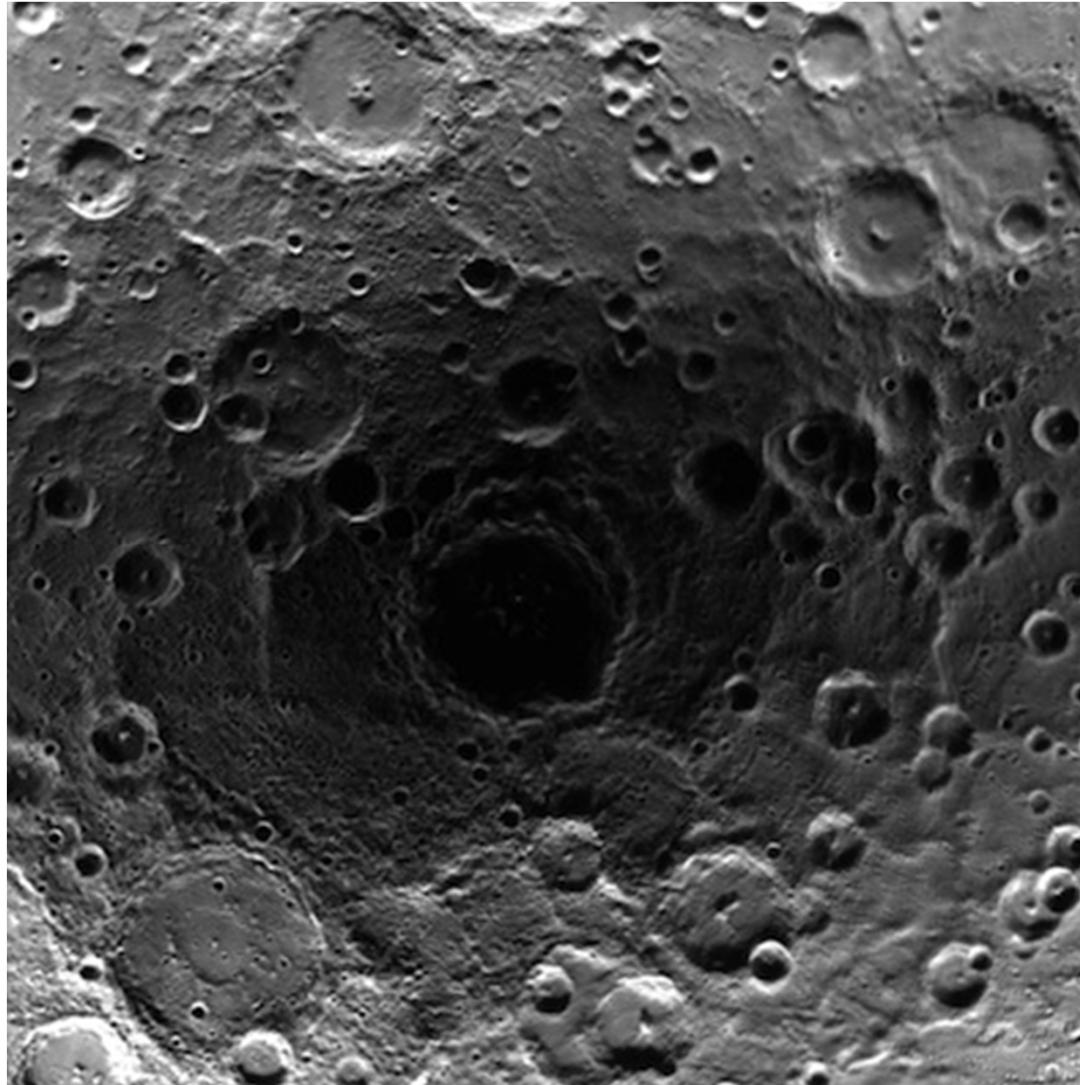
- Limited $75 \leq \text{PixelResolution} \leq 800$ meters/pixel
- Used FASTX feature detector, SIFT descriptor extractor and BruteForce matcher
- From 101,177 images, 100,432 (99.2%) were successfully controlled
 - Of those, 1,332 (1.3%) had convex hull ratios $< .30$
- Control network totals:
 - Number images controlled: 100,432
 - Total control points: 12,596,336
 - Total tie points: 94,745,475
 - By far, the largest control network processed in ISIS3!
- Average residual: 0.85 pixels

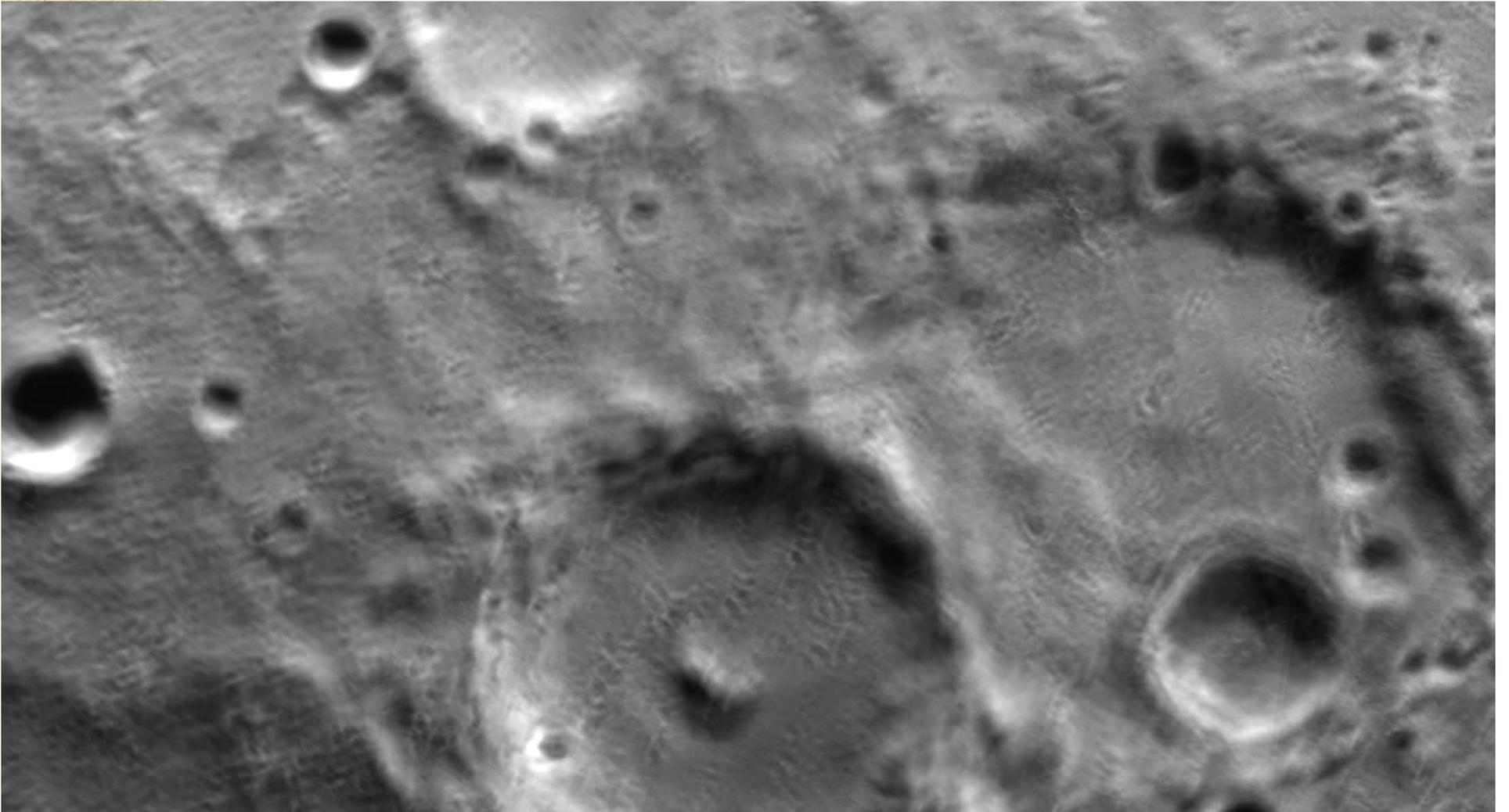
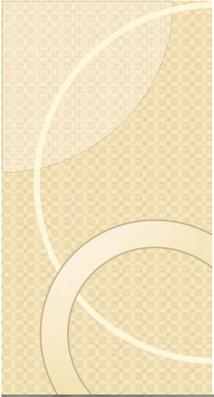
Application of Control

- Produced global DEM and smithed CK kernel from control process
- Applied MDIS image control and used DEM to orthorectify 1092 Mercury southern hemisphere images and produce **average** mosaic
- Following slides show differences of average mosaics comprised of all 1,092 images
 - Comparison of uncontrolled vs controlled map
 - Comparison at full resolution (200 m/p)
 - Image depth map at each pixel (up to 175 images!)

Uncontrolled vs Controlled Maps

Mercury South Pole Mosaic







PDS and ISIS

Supported Viewers

- J-MARS for Asteroids
- PSI Data Viewer
- USGS/PDS Cartographic and Imaging Node
 - Map-a-Planet 2
 - PILOT
 - Higher-order products of small bodies



Current support for Small Bodies

- NEAR
- Hayabusa
- Dawn
 - Vesta
 - Ceres
- New Horizons
- *Messenger*
 - *(Mercury is a really large small body)*

In the Works

- Rosetta (Funded thru PMDAP)
 - OSIRIS WA/NA
 - VIRTIS
- Hayabusa-2 (Waiting on H2PSP)
- OSIRIS-REx (Cooperative Agreement)
- ALMA, etc (SSO as a pilot study)
- Improving the oblique solutions
- Next ISIS Releases
 - 24th March
 - 28th July (Improving the oblique solutions)



Summary: Why use ISIS?

- Orthorectify (Map Project) Images
- Data Fusion
- DTM Generation
- Cartographic mosaics
- Control Networks
- Maps
- **Adds Value to your data!**
- Allows the community to use your data!

Regional Planetary Image Facility (RPIF)



Gene doing Apollo and Gemini
astronaut training at Meteor
Crater

- Shoemaker collection
- Impacts & Explosions collection
- Material on mapping small bodies

USGS Asteroid Resource Assessment

- Spurring Private Aerospace Competitiveness & Entrepreneurship Act of 2015,
 - by the President on November 25, 2015,
 - 180 days to provide a report on space resources.
- USGS Focus is:
 - Platinum
 - Water
 - Native metals.
- See Kestay's Poster at LPSC